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A NEW TOOL FOR ACCURATELY MEASURING THE INSIDE  
DIAMETER OF A GUN BARREL, LONG TUBE, OR SIMILAR

NAVAL ORDNANCE LABORATORY

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**A NEW TOOL FOR ACCURATELY MEASURING THE INSIDE DIAMETER OF A GUN BARREL,  
LONG TUBE, OR SIMILAR**

**BY  
J. Pauwe**

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A NEW TOOL FOR ACCURATELY MEASURING THE INSIDE DIAMETER OF A GUN  
BARREL, LONG TUBE, OR SIMILAR

The design and development of this new gage was the fulfillment of a long-time need. The necessity of the knowledge of the inside diameter and profile of a two-stage gun barrel gets more important with increasing launch velocities. Also, the number of shots per gun barrel is important (the longer a gun barrel can be used, the more economical the operation will be). When the shape of a gun barrel can be kept in the right condition, an important step toward successful launchings has been taken.

The development of this gage was done under the Naval Ordnance Laboratory, Ballistics Department's Maintenance and Improvement Program.

The author wishes to express his appreciation to Messrs. E. L. White and J. F. Meek for their assistance in the experimental part and the actual measuring operations.

ROBERT WILLIAMSON II  
Captain, USN  
Commander

*A. E. Seigel*  
A. E. SEIGEL  
By direction

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## INTRODUCTION

Measuring the inside diameter of the barrel of a two-stage launcher is a difficult and almost impossible job. The results with the available tools, such as a dial bore gage, Starr gage, or Spider gage, are questionable. As long as the length of a barrel is, for example, ten feet, one can measure the inside diameter fairly accurately, assuming it is possible to measure from both ends and the length to cover from each end is not more than, for example, five feet. Up to this length, it is reasonable to accept and expect an accurate measurement, within plus or minus 0.0005 inch. Yet, it is difficult, needs skill, and is time-consuming. Larger tubes and lengths over ten feet can still be measured with the aforementioned Starr or Spider gages, but the accuracy obtained is not high. Repeatability is poor, and if one needs real and true dimensions, there is no instrument available which gives the desired data in a short time, if at all. A good and accurate profile of the inside diameter of a long tube is very difficult to obtain.

One of the barrels in use in the Ballistics Department has a two-inch inside diameter and a length of eighty-one feet. This means a ratio of diameter and length of almost 1:500. In the past, measurements of the inside diameter were done with a Starr gage up to approximately three feet from the breech and three feet from the muzzle end inward. It is possible to go six or more feet inside, but the accuracy of measurements goes down proportionally with the length or depth of measuring inside the barrel and the uncertainty is larger. Then a good-fitting phenolic or polyethylene plug was made and pulled through the barrel, and the force to pull the plug through was measured. This "pull force" and the markings on the outside diameter of the plug were an indication of the condition of the inside diameter of the barrel.

It is clear that this method does not produce any accurate data at all and is only a rough estimate of the shape and conditions of the barrel. The only thing which can be proved is the minimum or smallest diameter of the barrel bore. It is interesting to note that different people obtained different results, and the various measurements even resulted in conflicting data.

Another method for measuring and checking the inside shape of the barrel is an optical system, whereby a so-called backlight target is used. The backlight target with cross-hair lines is pulled through the barrel, and the deflections are measured with a scope. This system is, in particular, used for straightness measurements and alignment of the barrel, but occasionally is tried for diameter measurements. This system is complicated, time-consuming, and

"repeat" accuracy is difficult to obtain. When the barrel is not straight, diameter measurements are not possible.

The newly developed measuring tool not only is an answer to the question of measuring the inside diameter, but proves to be a tool which really gives a clear view of the inside condition of the barrel. For example, there had been a difference of opinion about the "crimping" effect of a heavy bracket clamped around the barrel. According to some, the inside diameter was measurably smaller at the location of the bracket. This thought was definitely not accepted by others. The "pro's" measured the effect of the outer bracket by carefully measuring the inside diameter with the bracket bolts tightened and with the bolts just hand tight, thus arriving at their observations. The next time the barrel was measured, the "opposite" party did the measurements and promptly came up with a different result and measured no effect of the bracket at all. Interesting enough, nobody ever complained about the joints of the barrel sections, and as we will see, this should have been done.

When accurate measurements were taken with the new tool, we found an interesting phenomenon. The inside diameter of the barrel showed two areas where the diameter changes were larger and more irregular than the average pattern. These bad spots were exactly at the joints of the barrel sections, and the joints definitely affected the inside diameter over a length of several feet before and after the joint. The diameter at the bracket location did not change, whether the bracket was tightened on the barrel or not. Figure 1 shows the results of the inside diameter measurements taken at six-inch intervals.

## BORE TOOL

### General

The new tool which has been developed for measurement of the inside diameters of long barrels, tubes, etc., overcomes all the problems of the other systems. The new tool can be used in any location and gives very high accuracy in the diameter measurements. Its use reduces the time of measurements considerably and does not need special handling or skilled hands. The important thing is that it is possible now to measure accurately any spot or area inside the barrel. The length of the barrel, pipe, or tube is not important, and there is no restriction anymore for reliable and accurate measurements. Measurements can be repeated within very small tolerances, depending on the recording or readout instruments used. There are a few conditions for operation. The bore has to be clean and without heavy damages or grooves, and the surface of the inside diameter should be smooth, preferably honed. Secondly, the bore tool has to be adjusted and made ready for the particular diameter. The measuring range is small in comparison with other instruments. Thirdly, for accurate measurements, the bore tool has to be calibrated before and after the "measuring run."

In measuring the inside diameter of a tube or barrel, the tool is slowly pulled through the tube (barrel) and can give an automatic continuous readout on tape of the inside diameter (writing or pen recorder). The bore tool can be stopped and read at any distance or interval. Six-inch intervals are very attractive and give a real inside pattern of the barrel. The diameter can be read on a digital voltmeter or can be directly transferred in actual dimensions. Also, punch cards can be used, and via a computer, an accurate readout can be obtained later.

### Description

The instrument consists of a body holding a strain gage beam of certain length, Figure 2. The beam has a smaller area where on both sides (top and bottom) strain gages have been attached. The strain gage beam at one side is solidly tightened to the main tool body, whereas the opposite side is free to move up and down. This end of the beam has a button which, as said, can move a certain restricted distance up and down. The restriction is to prevent the beam from overstressing and causing permanent deflection.

The body at one end is supported by two solid bearing buttons and a third one is spring-loaded (this side is the opposite side from the moving beam button and on the same side where the beam has been fixed to the main body). The two bottom buttons are assembled in a movable or rotating bearing block in order to prevent the tool from "lifting" or "floating" on one side. The other side of the main body is the side where the measuring action takes place (see Figures 3, 4, and 5).

The strain gage beam is provided on both sides with a double set of strain gages which are temperature-balanced and wired in such a way that when the beam is slightly pushed down, the top strain gages under tension and the bottom strain gages under compression add displacement values. In this way, even the smallest amount of deflection is easily readable. The most simple form of readout is a digital voltmeter where the changes are recorded as microvolts. A calibration and simple calculation will transfer the digital readings into actual diameter readings. Since the muzzle end of the barrel is usually the biggest diameter, it is easy to adjust the tool for this diameter, thus assuring uninterrupted contact of the beam button with the inside diameter of the barrel (see Figure 6).

### PRINCIPLE OF MEASURING AND RECORDING

The basic principle of the new bore tool is that very small changes in diameter of the bore introduce a change in current. In our prototype, a semi-conductor strain gage bridge is used, Figure 7. The change in diameter of the barrel, when the tool is slowly pulled through the barrel, will change the current through the legs of the bridge, and these changes produce an unbalance voltage which is recorded by a digital voltmeter. The changes in current can also be

recorded by other means. Also, it is possible to use other devices such as three terminal capacitors instead of strain gages. Three terminal capacitors have often been used as transducers to measure accurately small displacements in air by measuring the change of capacitance as a guarded electrode moves with respect to a second electrode. Another way is measuring a straightforward electrical resistance change in a leg of a Wheatstone bridge. In this case, the changes in diameter move a contact over a current-carrying wire, and the wire is one of the legs of a Wheatstone bridge. Because of the small diameter changes, the movements are enlarged by a lever system.

#### METHOD OF MEASURING

The actual measuring operation, as said, is simple, considering a few preparations which have to be taken.

a. The tool has to be adjusted for the particular bore size. Once this has been done, it does not need to be repeated until the changes in diameter become too large and the tool cannot cover the measuring range. In the case of a barrel, it is easy to accomplish, since the muzzle end usually is the largest diameter and, as it is in our case also, the side where honing and cleaning operations start. Measurements are taken of the muzzle end (or the largest part of the barrel) with the tool adjusted accordingly.

b. Special calibration cylinders have been made to adjust and calibrate the tool. Two of these "standard" cylinders have a different inside diameter: Cylinder 1 has an inside diameter of 2.0228 inches, and cylinder 2 has an inside diameter of 2.0028 inches resulting in a difference in diameter of 0.0200 inch (see Figure 8). These two cylinders serve for calibration of the bore tool, whereas a third cylinder is used for diameter adjustment and confirmation of the calibration. The third cylinder has at one end a micrometer screw and, as said, is in the first place used for diameter range control, but can also be used for direct calibration purposes (see Figures 9 and 10).

c. The barrel should be cleaned and honed before the measurement operation. When the bore measuring tool or bore gage has been adjusted and calibrated, the measurement can take place. A tape of sufficient length, for example, 100 feet, is brought into the barrel and at the other side attached to the bore gage. Then slowly step by step, the tool can be pulled through the barrel. Intervals of six inches are small enough steps to obtain an accurate pattern of the inside diameter of the barrel. After the bore gage has been pulled through, it is good practice to check the calibration and measure the barrel a second time. Since the sensitivity is high, slightly different readings might be observed also due to a small difference in actual location of the bore gage, 0.0003 inch. An average value can be taken for the computation of the diameters.

Also, it is preferred to move the bore gage in one direction in order to prevent shattering of the gage beam. Pulling the bore

gage back and forth has been done without difficulty; as long as the gage beam can relax, there seems to be no problem. Relaxing the gage beam can easily be done by pulling in the "wrong" direction, for example, eight inches, and pulling back in the right direction two inches.

#### RESULTS AND CONCLUSION

With the availability of the new tool or gage, an excellent pattern of the inside diameter of a barrel can be obtained. When the gage is adjusted correctly, the measuring operation of an 80-foot barrel would not take more than one hour. With six-inch intervals, a total of 160 diameter measurements gives the profile of the inside diameter and shape of the barrel. The result is an authoritative answer to a question which never before could be answered or only estimated at the best.

The results of the measurements depend on the calibration and electronic instruments used. The accuracy of measurements can be better than 0.0002 inch. When the average accuracy over the total length of a barrel is between 0.0005 inch and 0.001 inch, an excellent profile of the inside diameter has been obtained. There are no more guesses or estimates of the inside diameter, and with the availability of new honing tools, the honing operation itself is going to be much more effective and efficient. The barrel can be kept in a better condition than before and, consequently, can be used much longer.

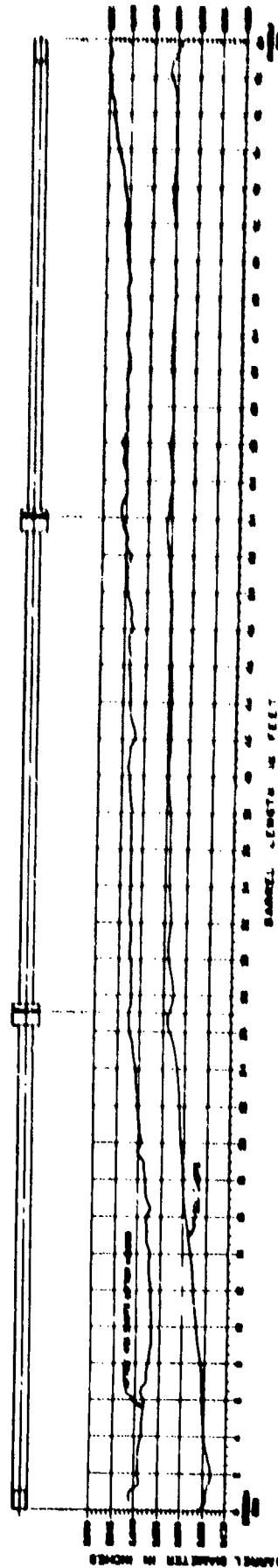
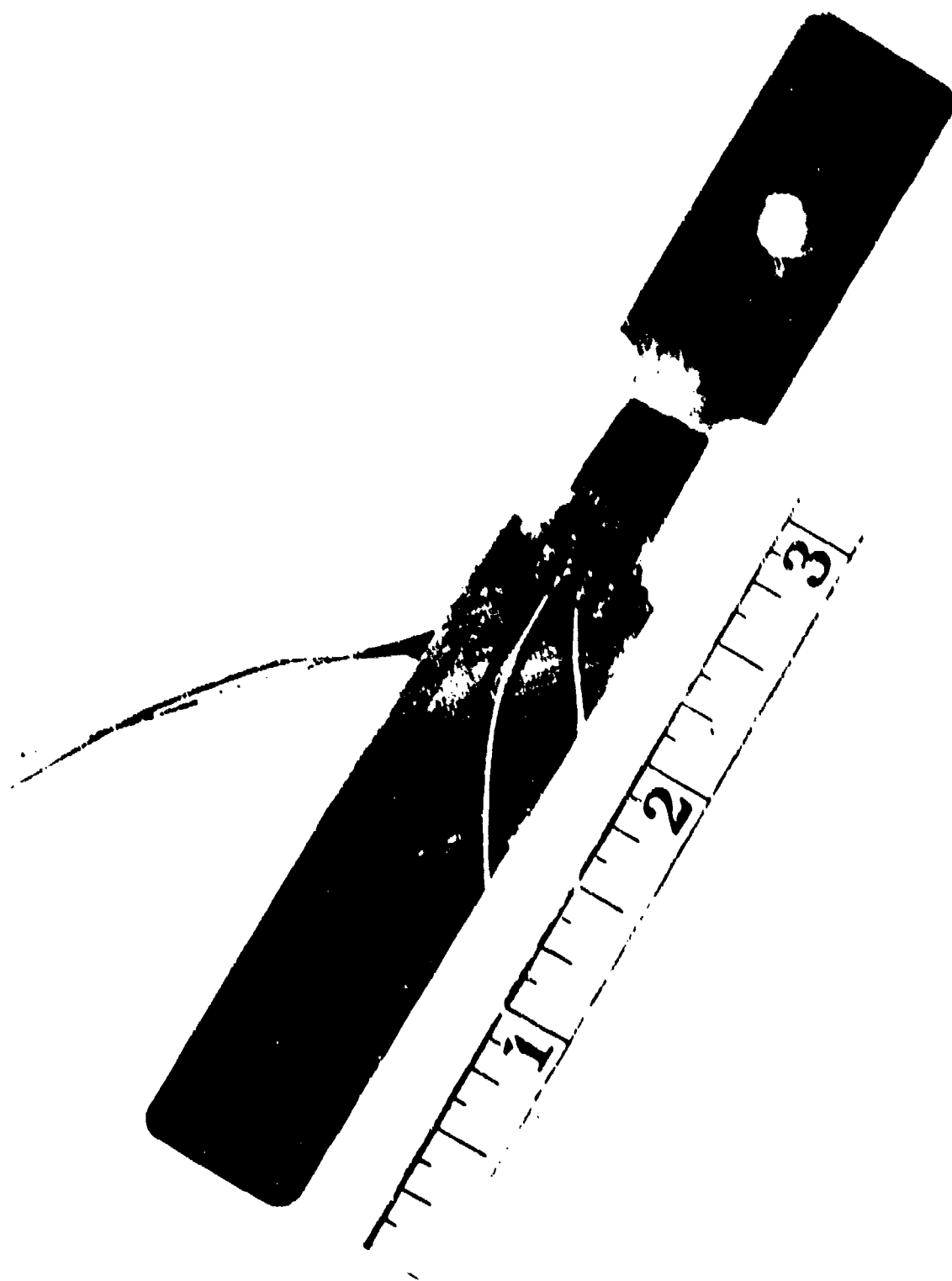


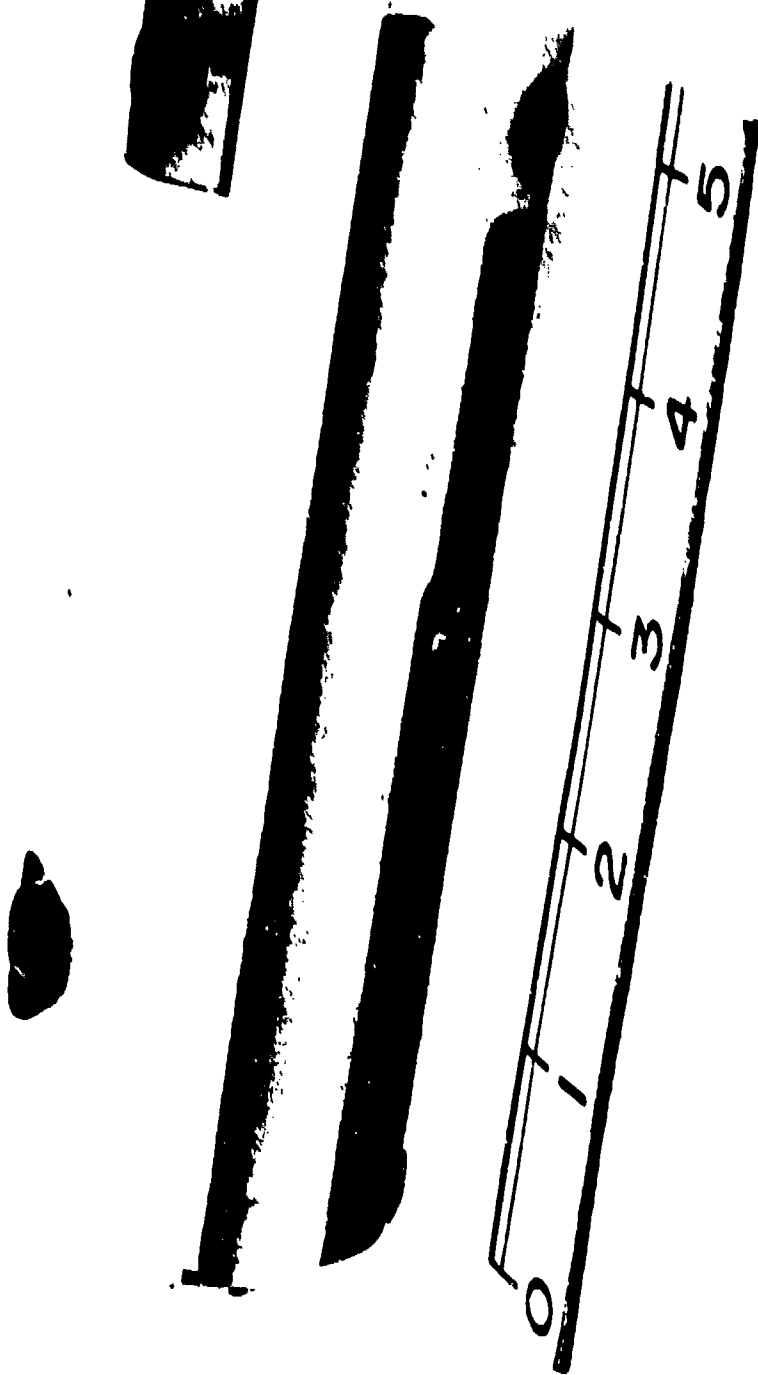
FIG. 1 BARREL-BORE MEASUREMENTS FOR 2 INCH-TWO STAGE GUN

PLATE 10

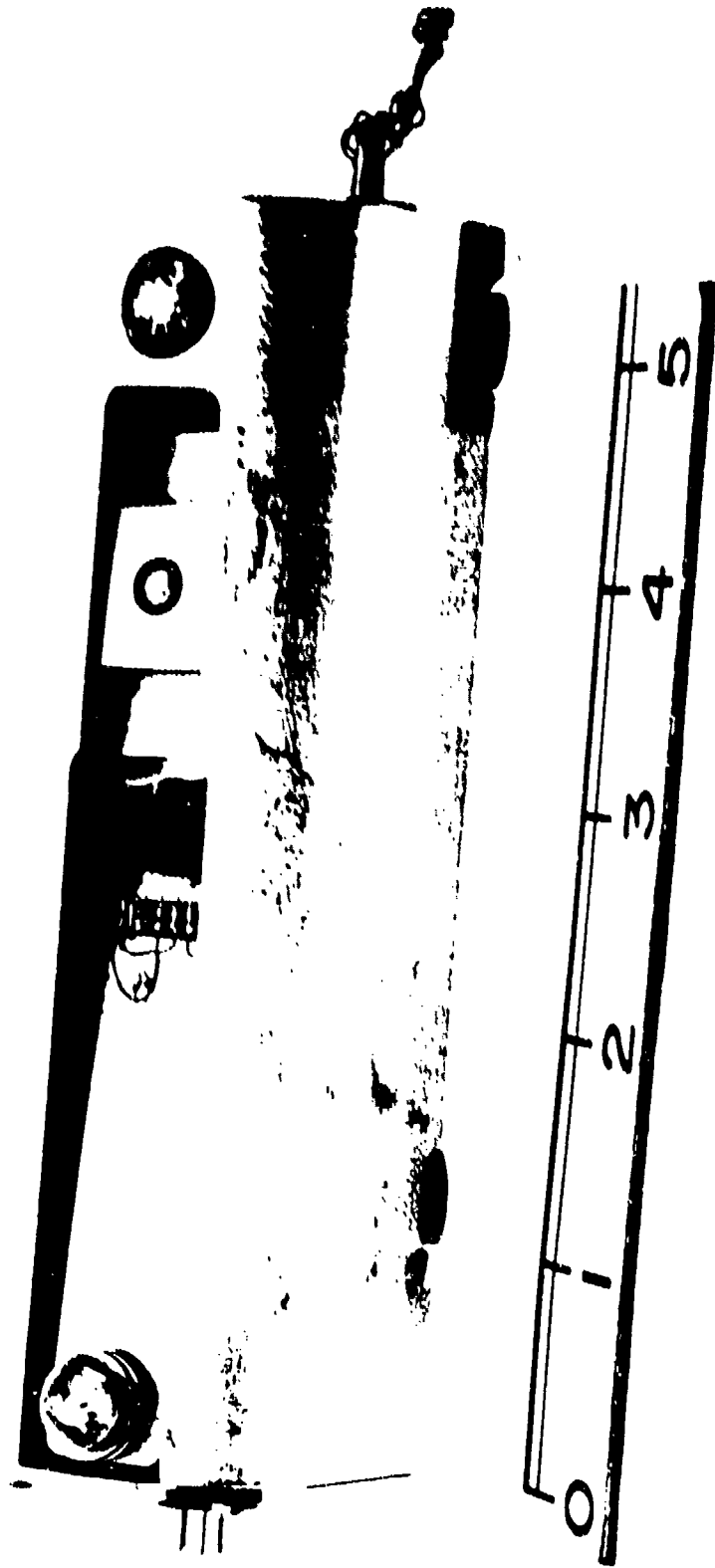


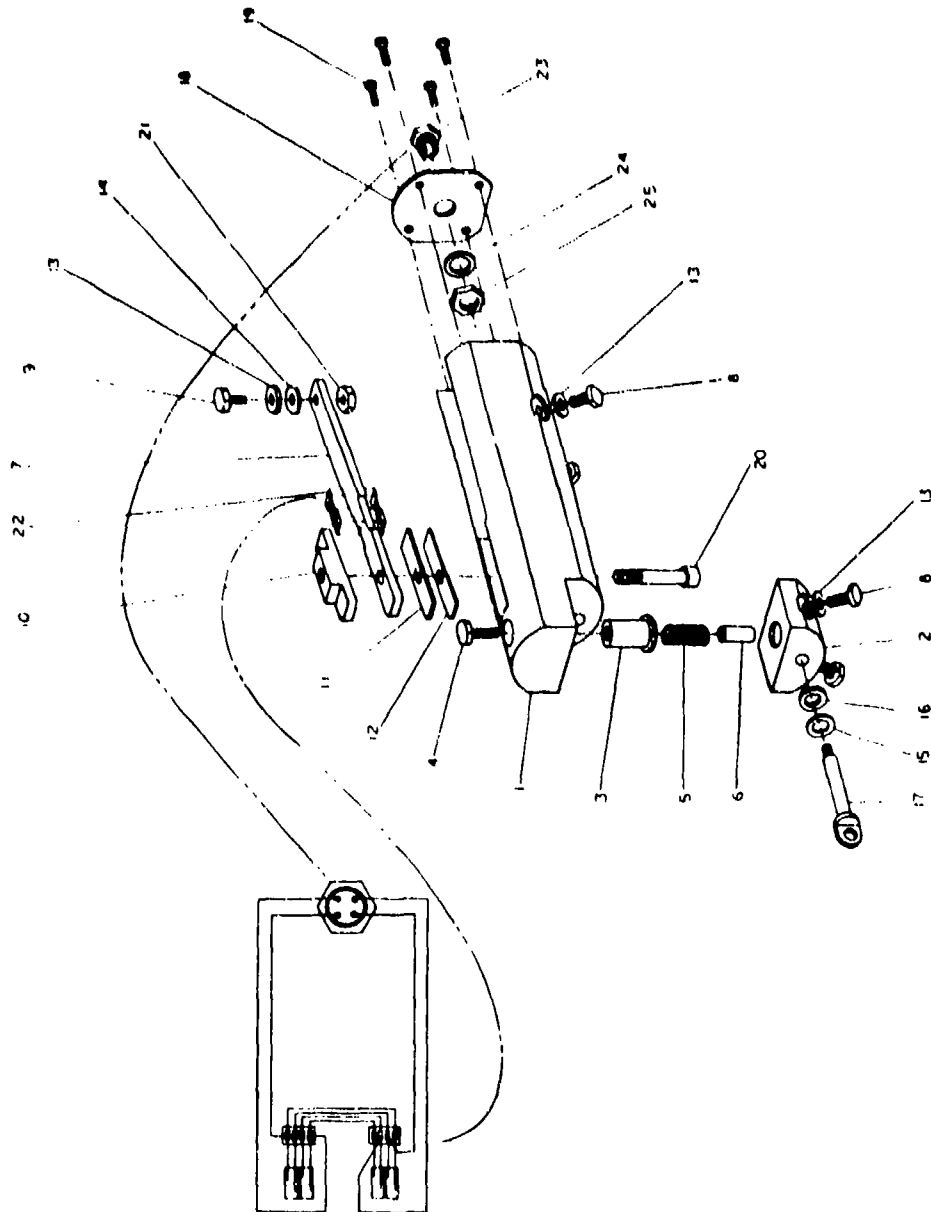


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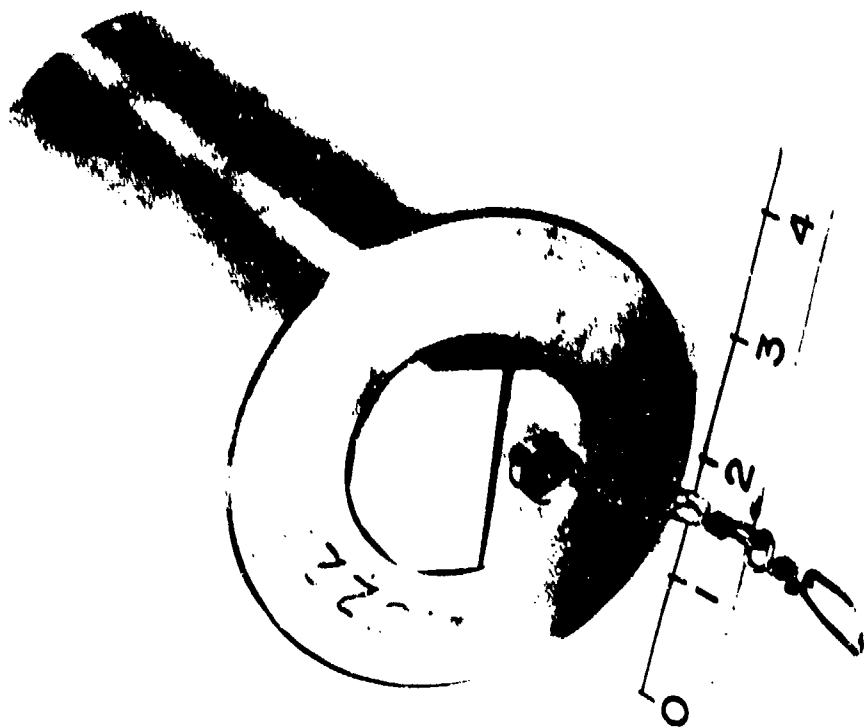
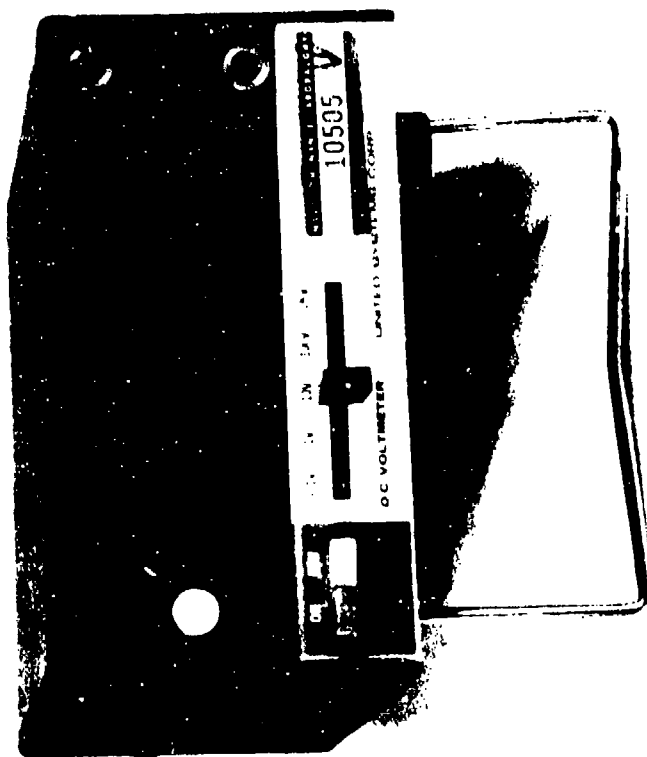


GUN BARREL I.D. GAGE

FIGURE 5 EXPLODED DRAWING OF BORE GAGE

NO.	IDENTIFYING NO.	DESCRIPTION	QTY	REMARKS
1	72-E-534	GUN BARREL I.D. GAGE	1	
2	72-B-1392	BODY	1	
3	72-C-143	LEG	1	
4	72-C-149	DETENT SPRING	1	
5	72-C-104	DETENT	1	
6	72-B-105	SPRING	1	
7	72-B-106	DETENT NUT	1	
8	72-B-107	WASHER	1	
9	72-B-108	WASHER	1	
10	72-B-109	WASHER	1	
11	72-B-110	WASHER	1	
12	72-B-111	WASHER	1	
13	72-B-112	WASHER	1	
14	72-B-113	WASHER	1	
15	72-B-114	WASHER	1	
16	72-B-115	WASHER	1	
17	72-B-116	WASHER	1	
18	72-B-117	WASHER	1	
19	72-B-118	WASHER	1	
20	72-B-119	WASHER	1	
21	72-B-120	WASHER	1	
22	72-B-121	WASHER	1	
23	72-B-122	WASHER	1	
24	72-B-123	WASHER	1	
25	72-B-124	WASHER	1	

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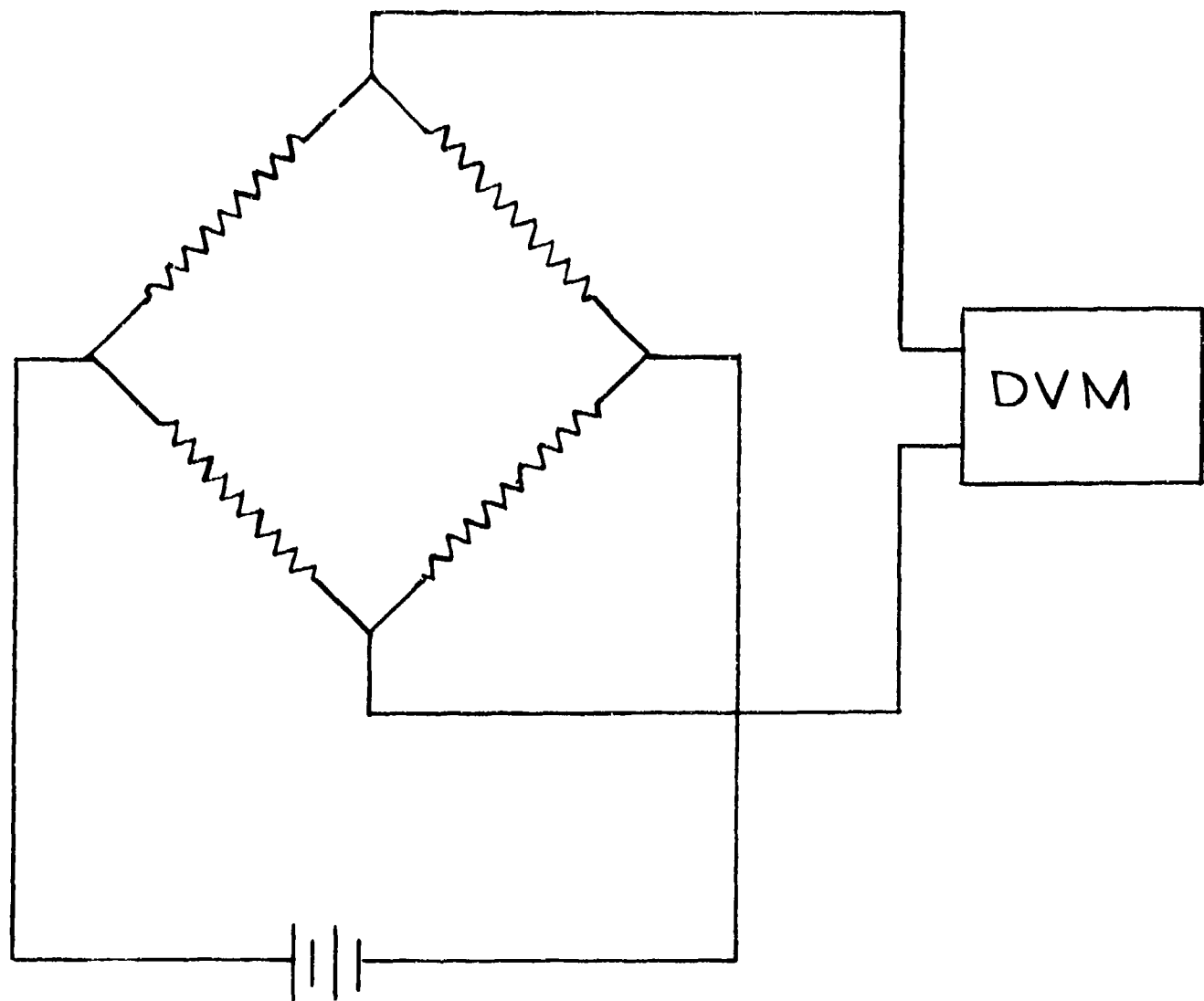


FIGURE 7 ELECTRIC DIAGRAM OF STRAIN GAGES



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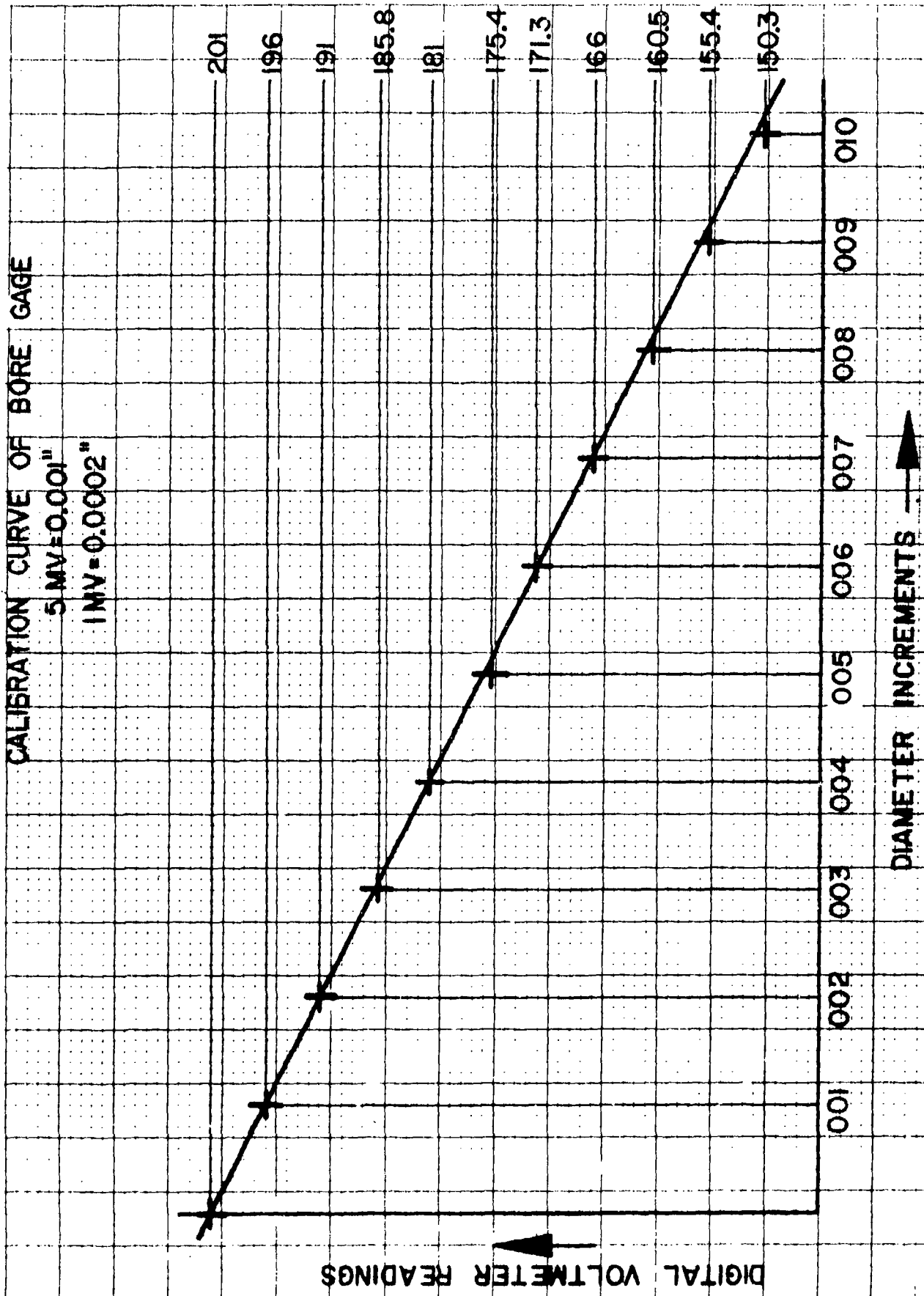


FIGURE 1- CALIBRATION DIAGRAM